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Total and labile organic carbon content in agroecological system

Conteúdo de carbono orgânico total e lábil do solo em sistema agroecológico

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RESUMO: Em sistema de consórcio alface-cenoura submetido a doses crescentes de composto orgânico (0, 12, 24, 48 Mg ha^{-1}) foram monitorados o carbono da biomassa microbiana do solo (CBM), carbono lábil de solo fumigado (CLF), não fumigado (CLNF), solo autoclavado (CLA) e carbono orgânico total (COT) na profundidade de 0-10 cm. Solo de pastagem e floresta adjacentes ao experimento foram usados como referência. Amostras de solo foram coletadas aos 8 dias antes da instalação, 0, 6, 60 e 114 dias após adubação. O CLF foi quem apresentou correlação mais consistente com o COT, atributo mais utilizado para detectar mudanças no conteúdo de matéria orgânica do solo. O aumento das doses de composto orgânico aumentou o conteúdo de CBM, CLF, CLNF, CLA e COT. A partir dos 60 dias após plantio, CBM e CLF apresentaram redução de seus níveis em função da qualidade do composto orgânico. Os solos de pastagem e floresta comportaram-se como contrastes, contendo menor e maior conteúdo de carbono do solo, respectivamente.

PALAVRAS-CHAVE: Matéria orgânica; biomassa microbiana; decomposição; solo fumigado; composto orgânico.

ABSTRACT: In an intercropping lettuce-carrot system submitted to crescent dosages of organic compost (0; 12; 24; 48 Mg ha^{-1}) were monitored carbon from soil microbial biomass (MBC), labile carbon in fumigated soil (LCF), in non-fumigated soil (LCNF), in autoclaved soil (LCA) and total organic carbon (TOC) at 0-10 cm of depth. Pasture and forest areas surrounding the experiment were used as reference. Five samples from soil were evaluated at 8 days before the beginning of the experiment, 0; 6; 60 and 114 days after manuring (dam). LCF was the attribute that presented the most consistent correlation with TOC that is usually utilized to detect changes in soil organic matter. Increasing dosages of organic compost caused the increase of MBC, LCF, LCNF, LCA and TOC. From 60 days after planting and forward, MBC and LCF presented decrease of their levels according to the quality of organic compost. Pasture and forest soils behave as contrasts, holding lower and higher content of carbon of soil, respectively.

KEY WORDS: Organic matter; microbial biomass; decomposition; fumigated soil; organic compost.

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Introduction

Soil conservation has been the subject matter of several researchers and the reason for concern of several scientists all over the world. Soil losses due to agricultural land management are frequent and very intense and those losses comprise carbon stored in organic and inorganic forms. Then, it is necessary to dispose a method to analyze and predict, by a faster and precise way, the alteration level of soils and consequently, evaluate the sustainability of these agroecosystems.

New models of indicators must attend basic premises in order to be accepted: fastness and accurate answer to disturbances; reflect aspects of ecosystems functioning; to be promptly and economically accessible and universally distributed, and also to present specificity for the use on spatial or temporal models at the environment (HOLLOWAY & STORK, 1991).

In this sense, labile form of carbon in soil has been used as status checkers of environments submitted to different kinds of cultivation and top dressing, notably because it is an active component from organic matter in soil (GHANI et al., 2003), allowing to gather valuable information for a better understanding about environmental status, principally in agroecological systems.

However, in the case of carbon from microbial biomass in soil (MBC) specifically, despite its great contribution to scientific progress in several works, evidenced by its role of particular relevance as potential source of N, P, S and other nutrients for plants and as microbial reservoir (DE-POLLI & GUERRA, 2008). The MBC use in large scale is difficult to access for many reasons, as laboratorial capability demand, physical limitation related to the use of triplicates needed for analysis (SILVA et al., 2007) and chemical limitation applied at soil samples to promote microbial lysis (FRIGUETTO & SCHNEIDER, 2000), besides difficulties due to the low oxidative power of potassium dichromate and to the different interpretations about the exact turning point during titration (DUDA et al., 2005). Therefore, in agreement to the statement by Cardoso (2004), there are lacks to be fulfilled concerning the enhancement of methodologies for biomass determination.

The development of alternative methodologies is necessary concerning a better use of existent resources in laboratories and the efficiency as biocide. The use of sterilizations in autoclave at 100 °C during 60 minutes has been an important alternative method for labile carbon determination, and the quantification of its carbon content by colorimetric method developed by Bartlett & Ross (1988) presenting results sometimes promissory (DUDA et al., 2005), sometimes conflicting, mainly, due to the presence of humic compounds and/or metal in the extract that may interfere in the analysis, then the conventional method by Walkley & Black is needed to be executed together.

The objective of this work was to quantify carbon content in soil under organic crop system monitoring carbon from microbial biomass in soil, labile carbon in fumigated soil and in non-fumigated soil, labile carbon in autoclaved soil and total organic carbon, and the sensibility of that soil when exposed to crescent dosages of organic compost was also evaluated. Pasture and fragment of secondary forest areas surrounding the experiment were used as reference.

Material and methods

The experiment was performed at Integrated System of Agroecological Production (SIPA) - a technical cooperation project between Embrapa Agrobiologia, Embrapa Solos, Pesagro-Rio and Universidade Federal Rural do Rio de Janeiro, located in Seropédica, Rio de Janeiro, Brazil, at 22°46´ of latitude and 43°41´ of longitude at west, with 33m altitude. According to Köppen climate classification, the climate is Aw, characterized by rain at summer, and drought at winter. Average temperature at that region is 23.5 °C, maximum average 29.3 °C and minimum 19.2 °C and annual average pluvial precipitation rate ~1,200mm.

Evaluations were made between June and September of 2000 in pasture and secondary forest fragment areas of the surroundings as references, and in an Ultisol soil under lettuce and carrot intercropped in a randomized complete block experimental design with four treatments (0, 12, 24, 48 Mg ha^{-1} of organic compost) and five replicates.

All chemical analysis of the soil and organic compost were made according to SILVA (1999). Chemical analysis of organic compost presented levels of 128 g kg^{-1} of C; 9.7 g kg^{-1} of N; 7.6 g kg^{-1} of P; 3.5 g kg^{-1} of K; 4.8 g kg^{-1} of Ca; 0.7 g kg^{-1} of Mg; 30% of humidity and pH (water) of 6.6. The organic compost was applied by top dressing in plots of 2 m^2 (2 x 1 m) in its dry base, 0; 3.43; 6.86 and 13.72 kg plot^{-1}. The organic compost was done using 70% of various grasses, 10% of residual cultural and 20% of manure

Soil of plots contained 69.4% sand, 11.8% silt and 18.8% clay, and presented before planting pH (water) 6.4; 0.0 cmol$_c$ dm^{-3} of Al; 4.12 cmol$_c$ dm^{-3} of Ca; 1.57 cmol$_c$ dm^{-3} of Mg; 91.7 mg kg^{-1} of P; 134.8 mg kg^{-1} of K; 18.6 g kg^{-1} of organic matter; 10.8 g kg^{-1} of organic-C and 1.07 g kg^{-1} of Total-N. Soil of pasture had predominantly Cost-Cross and Transvala grasses, containing 92.0 % sand; 3.0 % silt and 5.0 % clay and presented pH (water) 5.8; 0.0 cmol$_c$ dm^{-3} of Al; 1.2 cmol$_c$ dm^{-3} of Ca; 0.8 cmol$_c$ dm^{-3} of Mg; 16 mg dm^{-3} of P; 82 mg dm^{-3} of K; 10.3 g kg^{-1} of organic matter; 6.0 g kg^{-1} of organic-C and 0.6 g kg^{-1} of Total-N. Secondary forest fragment presented predominant evergreen vegetation. Forest with declivous relief, composed mainly by Solanaceae, Leguminosae and Bignoniaceae, and soil containing, 71.0 % sand; 14.0 % silt and 15.0 % clay and presented pH (water) 4.2; 2.2 cmol$_c$ dm^{-3} of Al; 2.4 cmol$_c$ dm^{-3} of Ca; 1.4 cmol$_c$ dm^{-3} of Mg; 11 mg dm^{-3} of P; 130 mg dm^{-3} of K; 30.9 g kg^{-1} of organic matter; 17.9 g kg^{-1} of organic-C and 1.9 g kg-1 of Total-N.

Every soil collection was made concomitantly for all areas at 0-10 cm depth for monitoring the content of MBC, LCF, LCNF, LCA and TOC. Soil collections were composed by five samplings at 8 days before the beginning of the experiment, 0, 6, 60 and 114 days after manuring (dam). From plots under organic compost dosages, six simple samples were taken assembling a composed sample by plot and from pasture and forest areas ten simple samples were taken assembling a composed sample that were immediately homogenized and sieved for determination of MBC, LCF and LCNF content, while for LCA and TOC determination, the samples came from air-dried fine soil (ADFS)

Evaluation of MBC was made from fumigation-extraction method, modified by De-Polli & Guerra (2008), when LCNF and LCF were used for MBC estimative. Additionally, in recent researches LCNF and LCF was been used as new method to evaluate soil quality (DE-POLLI et al., 2007). Fumigation was performed by direct adding of 1 mL of ethanol-free chloroform at each soil sample of 20g in 100mL tubes kept closed and in darkness during 24 hours and then opened inside an exhaustion hood and left for one hour in order to evaporate chloroform (BROOKES et al., 1982; WITT et al., 2000). Subsamples were taken (three for fumigation and three kept without fumigation) of 20g of soil (humid base) that received 50 mL of K_2SO_4 0.5 mol L^{-1}, and were agitated during 30 minutes and left for decantation for more 30 minutes, filtrated in medium filtration paper for separation of 8mL aliquot of the extract; added with 2 mL of $K_2Cr_2O_7$ 0.066 mol L^{-1}; 10 mL of H_2SO_4 PA and 1 mL of H_3PO_4, cooled; completed with distilled water and titrated with ferrous ammonium sulfate 0.038N.

TOC was determined by heat oxidation with potassium dichromate and titration with ferrous ammonium sulfate (WALKLEY & BLACK). LCA was obtained from 2g of ADFS sample in 20 mL of water into 100mL tubes covered with aluminum foil and autoclaved at 100 °C during one hour, and the carbon was quantified by colorimetric method developed by Bartlett & Ross (1988) that utilizes potassium permanganate as oxidative agent. Carbon concentration calculation is made using the equation of the line found, obtained from standard curve:

$$C \text{ (mg L-1)} = [(\text{Abs} - a)/b] \text{ x } [V/P] \text{ x } f.$$

Where:
C = carbon concentration;
Abs = absorbance of analysed sample;
a = intercept of the line found in standard curve;
b = angular coefficient of the line;
V = volume used in extraction;
P = dry weight of the soil;
f = dilution factor.

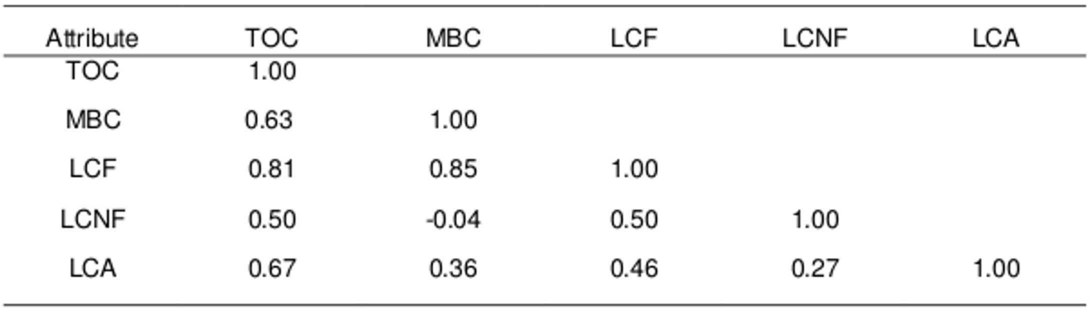
Results were submitted to analysis of variance, comparison of means using Tukey test at 5% level of significance and analysis of correlation by SISVAR program (FERREIRA, 2000).

Results and discussion

Results obtained for MBC, LCF, LCNF and LCA indicates that LCF presented better correlation with control method (TOC) (Table 1). In a general way, the attributes presented a significant increase, and later in time a significant decrease, of the carbon content in soil from the plots as the dosages of organic compost increased (Table2). Chemical quality of organic compost influenced MBC and LCF response that presented significant decreases for 12, 24 and 48 Mg ha^{-1} dosages from 60 days after planting and forward. Pasture soil presented, in general, the least contents of carbon in soil equal to the 0 Mg ha^{-1} organic compost dosage and forest soil presented values equal to the 48 Mg ha^{-1} organic compost dosage, therefore pasture and forest soils actually behaved as reference areas.

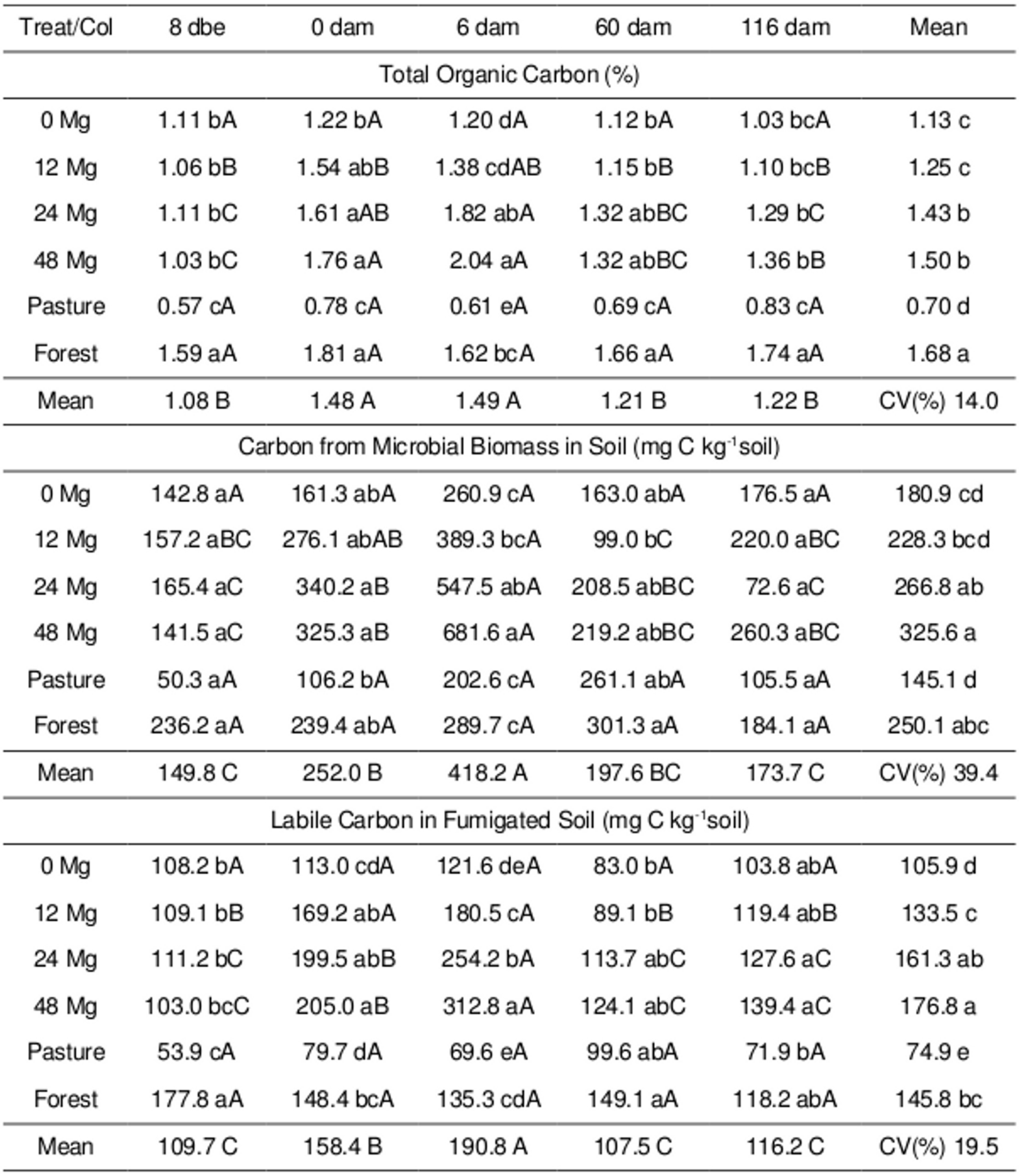
According to Table 1, the correlation between TOC x LCF was 0.81. Most of the obtained correlations were positive and consistent, when between 0.70 and 0.90, for TOC x LCF and MBC x LCF and medium, when between 0.5 and 0.7, for TOC x MBC, TOC x LCA, TOC x LCNF and LCF x LCNF, revealing that the quality of the organic compost may have influenced the response from attributes. Correlations below 0.50 were considered null according to Caromano et al. (2003) (Table 1). Results evidenced that only the correlations TOC x LCF and MBC x LCF were high and that, in this work, the positive response presented by LCF may

Table 1: Correlation matrix between total organic carbon (TOC), carbon from microbial biomass in soil (MBC), labile carbon in fumigated soil (LCF) and in non-fumigated soil (LCNF) and labile carbon in autoclaved soil (LCA).

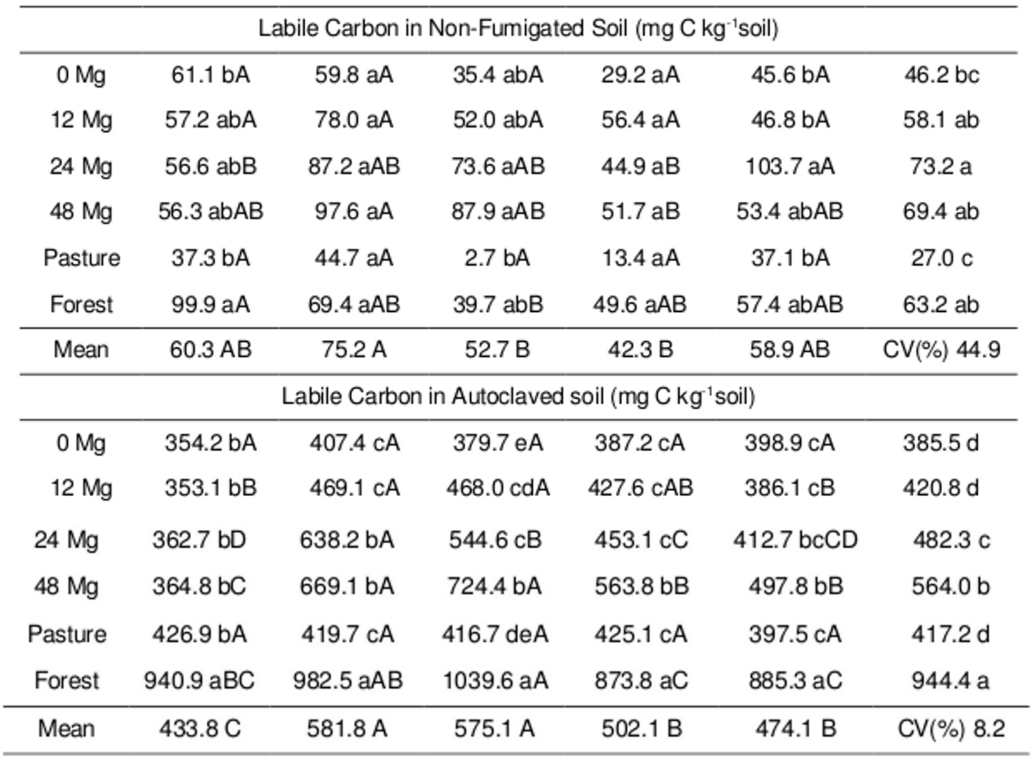


Attribute	TOC	MBC	LCF	LCNF	LCA
TOC	1.00				
MBC	0.63	1.00			
LCF	0.81	0.85	1.00		
LCNF	0.50	-0.04	0.50	1.00	
LCA	0.67	0.36	0.46	0.27	1.00

Table 2: Test of means between total organic carbon, carbon from microbial biomass in soil, labile carbon in fumigated soil and in non-fumigated soil and labile carbon in autoclaved soil within collections made at 8 days before beginning the experiment (dbe), 0, 6, 60 and 116 days after manuring (dam) submitted to treatments 0, 12, 24 and 48 Mg ha^{-1} of organic compost, pasture and forest.



Treat/Col	8 dbe	0 dam	6 dam	60 dam	116 dam	Mean
			Total Organic Carbon (%)			
0 Mg	1.11 bA	1.22 bA	1.20 dA	1.12 bA	1.03 bcA	1.13 c
12 Mg	1.06 bB	1.54 abB	1.38 cdAB	1.15 bB	1.10 bcB	1.25 c
24 Mg	1.11 bC	1.61 aAB	1.82 abA	1.32 abBC	1.29 bC	1.43 b
48 Mg	1.03 bC	1.76 aA	2.04 aA	1.32 abBC	1.36 bB	1.50 b
Pasture	0.57 cA	0.78 cA	0.61 eA	0.69 cA	0.83 cA	0.70 d
Forest	1.59 aA	1.81 aA	1.62 bcA	1.66 aA	1.74 aA	1.68 a
Mean	1.08 B	1.48 A	1.49 A	1.21 B	1.22 B	CV(%) 14.0
			Carbon from Microbial Biomass in Soil (mg C kg^{-1}soil)			
0 Mg	142.8 aA	161.3 abA	260.9 cA	163.0 abA	176.5 aA	180.9 cd
12 Mg	157.2 aBC	276.1 abAB	389.3 bcA	99.0 bC	220.0 aBC	228.3 bcd
24 Mg	165.4 aC	340.2 aB	547.5 abA	208.5 abBC	72.6 aC	266.8 ab
48 Mg	141.5 aC	325.3 aB	681.6 aA	219.2 abBC	260.3 aBC	325.6 a
Pasture	50.3 aA	106.2 bA	202.6 cA	261.1 abA	105.5 aA	145.1 d
Forest	236.2 aA	239.4 abA	289.7 cA	301.3 aA	184.1 aA	250.1 abc
Mean	149.8 C	252.0 B	418.2 A	197.6 BC	173.7 C	CV(%) 39.4
			Labile Carbon in Fumigated Soil (mg C kg^{-1}soil)			
0 Mg	108.2 bA	113.0 cdA	121.6 deA	83.0 bA	103.8 abA	105.9 d
12 Mg	109.1 bB	169.2 abA	180.5 cA	89.1 bB	119.4 abB	133.5 c
24 Mg	111.2 bC	199.5 abB	254.2 bA	113.7 abC	127.6 aC	161.3 ab
48 Mg	103.0 bcC	205.0 aB	312.8 aA	124.1 abC	139.4 aC	176.8 a
Pasture	53.9 cA	79.7 dA	69.6 eA	99.6 abA	71.9 bA	74.9 e
Forest	177.8 aA	148.4 bcA	135.3 cdA	149.1 aA	118.2 abA	145.8 bc
Mean	109.7 C	158.4 B	190.8 A	107.5 C	116.2 C	CV(%) 19.5



Labile Carbon in Non-Fumigated Soil (mg C kg^{-1}soil)						
0 Mg	61.1 bA	59.8 aA	35.4 abA	29.2 aA	45.6 bA	46.2 bc
12 Mg	57.2 abA	78.0 aA	52.0 abA	56.4 aA	46.8 bA	58.1 ab
24 Mg	56.6 abB	87.2 aAB	73.6 aAB	44.9 aB	103.7 aA	73.2 a
48 Mg	56.3 abAB	97.6 aA	87.9 aAB	51.7 aB	53.4 abAB	69.4 ab
Pasture	37.3 bA	44.7 aA	2.7 bA	13.4 aA	37.1 bA	27.0 c
Forest	99.9 aA	69.4 aAB	39.7 abB	49.6 aAB	57.4 abAB	63.2 ab
Mean	60.3 AB	75.2 A	52.7 B	42.3 B	58.9 AB	CV(%) 44.9
Labile Carbon in Autoclaved soil (mg C kg^{-1}soil)						
0 Mg	354.2 bA	407.4 cA	379.7 eA	387.2 cA	398.9 cA	385.5 d
12 Mg	353.1 bB	469.1 cA	468.0 cdA	427.6 cAB	386.1 cB	420.8 d
24 Mg	362.7 bD	638.2 bA	544.6 cB	453.1 cC	412.7 bcCD	482.3 c
48 Mg	364.8 bC	669.1 bA	724.4 bA	563.8 bB	497.8 bB	564.0 b
Pasture	426.9 bA	419.7 cA	416.7 deA	425.1 cA	397.5 cA	417.2 d
Forest	940.9 aBC	982.5 aAB	1039.6 aA	873.8 aC	885.3 aC	944.4 a
Mean	433.8 C	581.8 A	575.1 A	502.1 B	474.1 B	CV(%) 8.2

qualify this attribute as a tangible alternative for determination of labile forms of carbon in soil (Table 2). In this sense, LCA stands out as the attribute that presented lower coefficient of variation among every attribute evaluated, which demonstrates the higher precision of the analysis and reliability to be used as soil indicator. The relation between TOC x MBC was considered medium (0.63), similar result was obtained by Monteiro & Gama-Rodrigues (2004) who observed positive correlations between TOC x MBC. Still, Perez et al. (2004) evaluated correlations between MBC with chemical and biological attributes in soil cultivated with soybean under different management systems at cerrado climate, and verified the existence of positive and strongly significant correlation between MBC and TOC in studied soils.

Analysis indicated that before the beginning of the evaluations, plots did not present differences between themselves and as crescent dosages of organic compost were top dressed, an increase of the values of TOC, MBC, LCF, LCNF and LCA was observed. As time went through the values of those attributes began to decrease, notably, from 60 days after planting and forward (Table 2). This result may be explained because labile carbon is a component from the organic fraction decomposed by microorganisms (ZOU et al., 2005), carbon is chemically stable with long structure being more resistant against degradation than labile fractions (FOX et al., 2006) and the most recalcitrant components are the most resistant against microbial decomposition and present longer time of permanence in soil (KRULL et al., 2003),.

Unnumbered factors may act upon organic matter decomposition, overall because of the interaction between climate conditions and mineral traits of the soil, particularly the regulatory effect of temperature, crucial for the stability of organic matter storages in soil (BRIONES et al., 2006). Trumbore (2000) measured fractions of ^{14}C from organic matter in soil, and concluded that the microbial activity was derived from vegetable remainder that was recently deposited, in this sense organic compost must have presented the same behavior, especially, because of the decrease of labile carbon content at 60 days after planting.

Quality of organic compost influenced the response of the attributes, once no difference was detected for MBC and LCF at 60 days after planting, possibly due to composition of the organic compost (128 g kg^{-1} of C and 9.7 g kg^{-1} of N), which may have reflected at the response of the attributes, indicating their sensibility in identifying this difference from 60 days after planting. Mtambanengwe & Mapfumo (2008) evaluating the impact of soil management upon labile carbon, verified that the applying of high quality material increased labile carbon in 60 cm of the soil profile. Therefore, chemical quality enhancement of the soil by the utilization of organic compost may be helpful to increase the quality of agricultural soil, indicating that microorganisms are influenced by labile carbon levels at easily assimilating forms in soil.

According to the results, the use of crescent dosages of organic compost promoted increase of the carbon content in soil that reached its maximum, in average, around six days after planting and as time went through those values decreased significantly at 60 days after planting. Control dosage evidenced that there were no changes in carbon content in the evaluated period for all attributes. Still pasture and forest soils presented variable behavior, indicating seasonal effect upon standard responses that may be related to abiotic conditions, above all, climate and local soil. Sand constitution of the pasture soil may have contributed to the lower carbon content in this condition, agreeing with Venkze Filho et al. (2008) who studied MBC in no-tillage system and verified that sand soils presented lower MBC and SIX et al (2002) who verified that in sand texture soils from regions of warmer climate the rate of decomposition of organic matter was higher, therefore the storage of organic matter in soil of agricultural systems is difficult (FLORES et al., 2008).

Levels of total organic carbon and labile carbon in forest soil were significantly equal to the 48 Mg ha^{-1} of organic compost dosage, possibly related to the quality of the organic compost used. High levels of Al in forest soil has been related by Souza et al. (2004) and Longo et al. (2005), which is explained by no fertilization or liming to correct Al levels, and no soil disturbance, which allows the maintenance of the original vegetation and consequently carbon conservation with high levels of TOC and labile carbon. Control treatment (0 Mg ha^{-1} organic compost) presented carbon contents in organic and labile forms significantly lower. Agricultural activity without the use of organic compost did not influence the content of MBC, LCF, LCNF, LCA and TOC, because there were no significant differences between collections within the studied period. Bayer et al. (2002) observed decreases of 36% of TOC in soil under conventional preparing when compared to forest and also that the no-tillage system resulted in a biologically less oxidative environment, favorable to preservation of the organic matter labile fractions, which in this work, is close to the soil condition under higher dosages of organic compost. Marchiori Jr. & Melo (2000) investigating alterations in organic matter and in microbial biomass under different managements, observed higher values of TOC in soil of natural forest, while higher values of MBC were found in agricultural soils, agreeing with the results about the effect of organic compost quality upon labile carbon forms such as MBC, suggesting that use of organic materials is an efficient strategy to improve soil quality.

The utilization of all attributes together must be objective in order to enhance the interpretation of the results (MONTEIRO & GAMA-RODRIGUES, 2004), the microbial biomass must be studied associated with other parameters and the indicators of soil quality must be available and accessible turning the method of microbial carbon quantification simpler, reliable (DUDA et al., 2005) and also economically viable. Considering that the labile forms of carbon may contribute to the organic carbon content in soil, the reported data about this subject matter is 48% in Alfisols and 11.1% in Ultisols, (ZOU et al., 2005) and 4.1% in Regosols (ANAYA et al., 2007) and agricultural practices alter physical, chemical and biological characteristics of the soil, LCF can be one more tool to be used in laboratories because of the promising results presented. LCF determination is relatively easy and therefore the carbon pool and the carbon turnover determination in soil turns out to be simple (ZOU et al., 2005).

Conclusions

Labile carbon in fumigated soil presented the most consistent correlation with total organic carbon.

The increase of the organic compost dosages caused the increase of the labile carbon content in fumigated soil, microbial biomass carbon in soil, labile carbon in fumigated soil, labile carbon in non-fumigated soil and labile carbon in autoclaved soil.

From 60 days after planting and forward, MBC and LCF presented decrease of their levels as a function of the quality of the organic compost.

Pasture and forest soils behaved as contrasts, containing lower and higher content of carbon in soil, respectively.

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